

## Claims

- [c1] 1. A protective coating on a silicon-containing surface, the protective coating having an outer surface region consisting essentially of one or more stoichiometric crystalline phases of barium-strontium aluminosilicate and being substantially free of a nonstoichiometric second crystalline phase of barium-strontium aluminosilicate that contains a substoichiometric amount of silica.
- [c2] 2. A protective coating according to claim 1, wherein substantially all of the protective coating consists essentially of the one or more stoichiometric crystalline phases of barium-strontium aluminosilicate and is substantially free of the nonstoichiometric second crystalline phase of barium-strontium aluminosilicate.
- [c3] 3. A protective coating according to claim 2, wherein the protective coating contains at least 47 molar percent silica.
- [c4] 4. A protective coating according to claim 2, wherein the protective coating consists of, by molar percent, about 25% barium oxide + strontia, about 25% alumina, about 50% silica, and incidental impurities, and strontia consti-

tutes less than 25 molar percent of the barium oxide + strontia content of the protective coating.

- [c5] 5. A protective coating according to claim 1, wherein the protective coating has a silica to BaO+SrO molar ratio at or above 2:1, has an alumina content of greater than 25 molar percent, and contains up to about 2 atomic percent of an alumina phase.
- [c6] 6. A protective coating according to claim 1, wherein the protective coating has a second region beneath the outer surface region, the second region containing the nonstoichiometric second crystalline phase.
- [c7] 7. A protective coating according to claim 6, wherein the outer surface region of the protective coating contains at least 47 molar percent silica and the second region of the protective coating contains less than 47 molar percent silica.
- [c8] 8. A protective coating according to claim 6, wherein the outer surface region of the protective coating consists of, by molar percent, about 25% barium oxide + strontia, about 25% alumina, about 50% silica, and incidental impurities, and strontia constitutes less than 25 molar percent of the barium oxide + strontia content of the protective coating.

- [c9] 9. A protective coating according to claim 6, wherein the outer surface region of the protective coating has a thickness of about 10 to about 25 micrometers.
- [c10] 10. A protective coating according to claim 1, wherein the protective coating is part of a barrier coating system on the silicon-containing surface, the barrier coating system further comprising at least one intermediate layer between the protective coating and the silicon-containing surface, the at least one intermediate layer containing a material chosen from the group consisting of silicon and mullite.
- [c11] 11. A protective coating for a silicon-containing surface of a gas turbine engine component, the protective coating being a part of a barrier coating system comprising at least one intermediate layer on which the protective coating is deposited, the at least one intermediate layer containing a material chosen from the group consisting of silicon and mullite, the protective coating consisting essentially of the stoichiometric crystalline celsian phase of barium-strontium aluminosilicate and not more than five volume percent of a nonstoichiometric crystalline lamella phase of barium-strontium aluminosilicate that contains a substoichiometric amount of silica.

- [c12] 12. A protective coating according to claim 11, wherein the protective coating contains at least 50 molar percent silica.
- [c13] 13. A protective coating according to claim 11, wherein the protective coating consists of, by molar percent, about 25% barium oxide + strontia, about 25% alumina, about 50% silica, and incidental impurities.
- [c14] 14. A protective coating according to claim 13, wherein strontia constitutes less than 25 molar percent of the barium oxide + strontia content of the protective coating.
- [c15] 15. A protective coating according to claim 11, wherein the protective coating has a silica to BaO+SrO molar ratio at or above 2:1, has an alumina content of greater than 25 molar percent, and contains up to about 2 atomic percent of an alumina phase.
- [c16] 16. A protective coating according to claim 11, wherein the protective coating is in an as-deposited condition.
- [c17] 17. A protective coating according to claim 11, wherein the barrier coating system has undergone engine operation and the protective coating is substantially free of pores formed by volatilization of the protective coating.

- [c18] 18. A process of forming a protective coating on a silicon-containing surface, the process comprising a deposition and at least a first heat treatment step that result in the protective coating having at least an outer surface region that consists essentially of one or more stoichiometric crystalline phases of barium-strontium aluminosilicate and is substantially free of a nonstoichiometric second crystalline phase of barium-strontium aluminosilicate that contains a substoichiometric amount of silica.
- [c19] 19. A process according to claim 18, wherein the protective coating is deposited by spraying a powder that contains more than 50 molar percent silica.
- [c20] 20. A process according to claim 18, wherein the protective coating is deposited by spraying a powder that contains at least 52 molar percent silica.
- [c21] 21. A process according to claim 18, wherein the protective coating is deposited by spraying a powder that has a silica to BaO+SrO molar ratio of greater than 2:1 and an alumina content of greater than 25 molar percent.
- [c22] 22. A process according to claim 18, wherein the protective coating is deposited so that substantially the entire protective coating consists essentially of BaO, SrO,  $\text{Al}_2\text{O}_3$

and  $\text{SiO}_2$  in approximately stoichiometric amounts for barium–strontium aluminosilicate, and after the first heat treatment step the protective coating consists essentially of the crystalline celsian phase of barium–strontium aluminosilicate and is substantially free of the nonstoichiometric second crystalline phase of barium–strontium aluminosilicate.

[c23] 23. A process according to claim 22, wherein the protective coating is deposited by spraying a powder that contains more than 50 molar percent silica.

[c24] 24. A process according to claim 23, wherein the powder consists essentially of, by molar percent, 18.7–19.1% BaO, 4.5–4.9% SrO, 25.1–26.1%  $\text{Al}_2\text{O}_3$ , and 50.4–51.4%  $\text{SiO}_2$ .

[c25] 25. A process according to claim 22, wherein the protective coating is deposited by spraying a powder that contains at least 52 molar percent silica.

[c26] 26. A process according to claim 25, wherein the powder consists essentially of, by molar percent, 18.4–18.8% BaO, 4.5–4.9% SrO, 23.4–24.4%  $\text{Al}_2\text{O}_3$ , and 52.3–53.3%  $\text{SiO}_2$ .

[c27] 27. A process according to claim 22, wherein the protective coating consists of, by molar percent, about 25%

barium oxide + strontia, about 25% alumina, about 50% silica, and incidental impurities.

- [c28] 28. A process according to claim 27, wherein strontia constitutes less than 25 molar percent of the barium oxide + strontia content of the protective coating.
- [c29] 29. A process according to claim 18, wherein the protective coating is deposited to contain non-stoichiometric amounts of BaO, SrO,  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  for barium-strontium aluminosilicate and following the first heat treatment step the protective coating contains the non-stoichiometric second crystalline phase, the process further comprising a second heat treatment step during which the outer surface region forms by volatilization of the nonstoichiometric second crystalline phase within the outer surface region and resultant porosity is sealed within the outer surface region.
- [c30] 30. A process according to claim 29, wherein the protective coating has a second region beneath the outer surface region, the second region containing non-stoichiometric barium-strontium aluminosilicate and the nonstoichiometric second crystalline phase.
- [c31] 31. A process according to claim 30, wherein the outer surface region of the protective coating contains at least

47 molar percent silica and the second region of the protective coating contains less than 47 molar percent silica.

[c32] 32. A process according to claim 29, wherein the second heat treatment step is a localized surface heat treatment of the outer surface region.

[c33] 33. A process according to claim 18, wherein the protective coating is deposited as part of a barrier coating system on the silicon-containing surface, the process further comprising the step of depositing at least one intermediate layer on the silicon-containing surface after which the protective coating is deposited on the at least one intermediate layer, the at least one intermediate layer containing a material chosen from the group consisting of silicon and mullite.

[c34] 34. A process of forming a protective coating on a silicon-containing surface of a gas turbine engine component, the protective coating being a part of a barrier coating system comprising at least one intermediate layer on which the protective coating is deposited, the process comprising the steps of:  
depositing the protective coating so that substantially the entire protective coating consists essentially of BaO, SrO,  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  in approximately stoichiometric



amounts for barium–strontium aluminosilicate; and heat treating the protective coating so that the protective coating consists essentially of the crystalline celsian phase of barium–strontium aluminosilicate and not more than five volume percent of a nonstoichiometric crystalline lamella phase of barium–strontium aluminosilicate that contains a substoichiometric amount of silica.

[c35] 35. A process according to claim 34, wherein the protective coating contains at least 50 molar percent silica following the depositing step.

[c36] 36. A process according to claim 34, wherein after the depositing step the protective coating consists of, by molar percent, about 25% barium oxide + strontia, about 25% alumina, about 50% silica, and incidental impurities.

[c37] 37. A process according to claim 36, wherein strontia constitutes less than 25 molar percent of the barium oxide + strontia content of the protective coating after the depositing step.

[c38] 38. A process according to claim 34, wherein the protective coating is deposited by spraying a powder consisting essentially of, by molar percent, 18.7–19.1% BaO, 4.5–4.9% SrO, 25.1–26.1%  $\text{Al}_2\text{O}_3$ , and 50.4–51.4%  $\text{SiO}_2$ .

[c39] 39. A process according to claim 34, wherein the protec–

tive coating is deposited by spraying a powder consisting essentially of, by molar percent, 18.4–18.8% BaO, 4.5–4.9% SrO, 23.4–24.4% Al<sub>2</sub>O<sub>3</sub>, and 52.3–53.3% SiO<sub>2</sub>.

[c40] 40. A process according to claim 34, further comprising the steps of installing the component in a gas turbine engine and conducting an engine test, after which the protective coating is substantially free of pores formed by volatilization of the protective coating.